SRF gun Commissioning Progress

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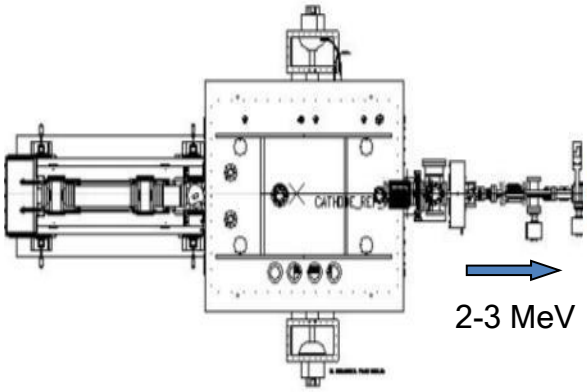
Outline

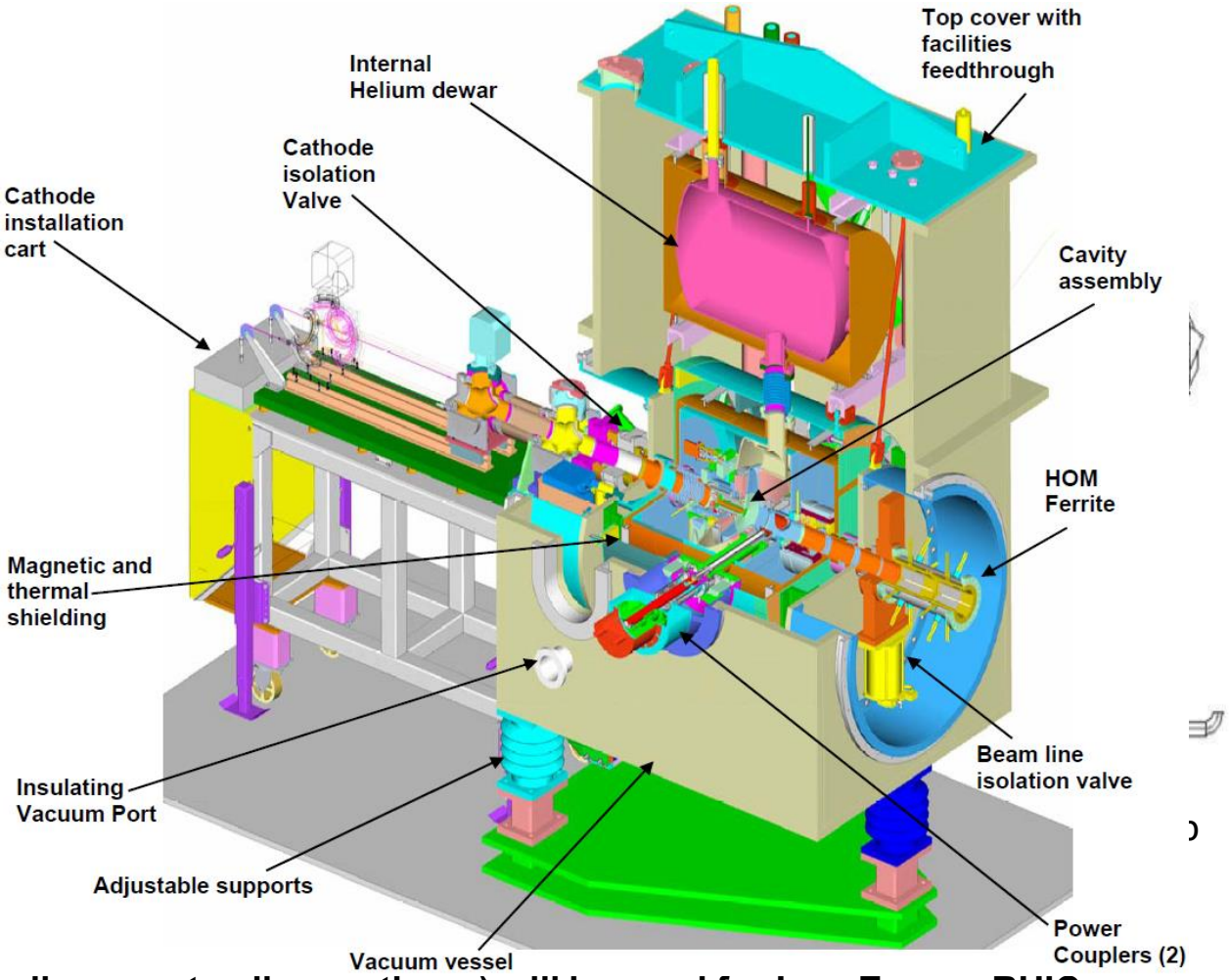
- Brief Introduction of the BNL R&D ERL and SRF gun
- Milestones of SRF gun building and commissioning
- First photoemission beam commissioning
- Summary

The R&D Energy Recovery Linac at BNL

SC RF Gun



2-3 MeV



- **Most of components (Gun, 5-cell, magnets, diagnostics…) will be used for Low Energy RHIC electron cooler (LEReC).**
- **5-cell cavity was commissioned up to 18 MV/m at pulse mode and 12 MV/m at CW mode.**
- **SRF gun is under commissioning.**

SRF gun Milestones

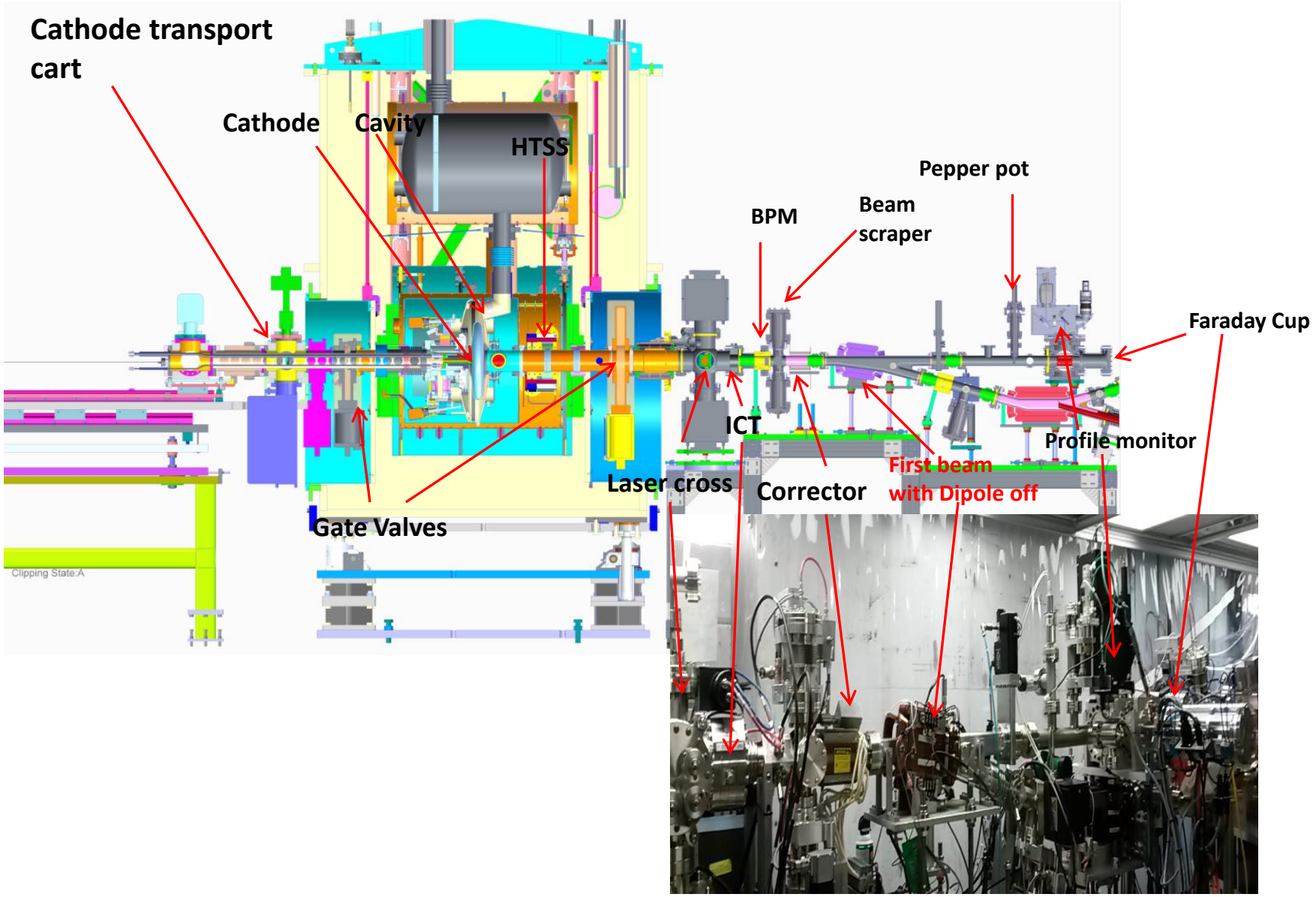
❖ Building up:

1. Mid. 2010: vertical cavity test in Jlab, reached 2.9 MV w/o cathode stalk. However, strong multipacting occurred with Nb cathode stalk.
2. Mid 2011: 500 kW CW fundamental power coupler conditioning.
3. 2011 to 2012: Installation of the whole cryostat.
4. 2011 to 2013: Preparation/commissioning the subsystems: cryo, LLRF, vac, instrumentation, cathode preparation system…

❖ Commissioning:

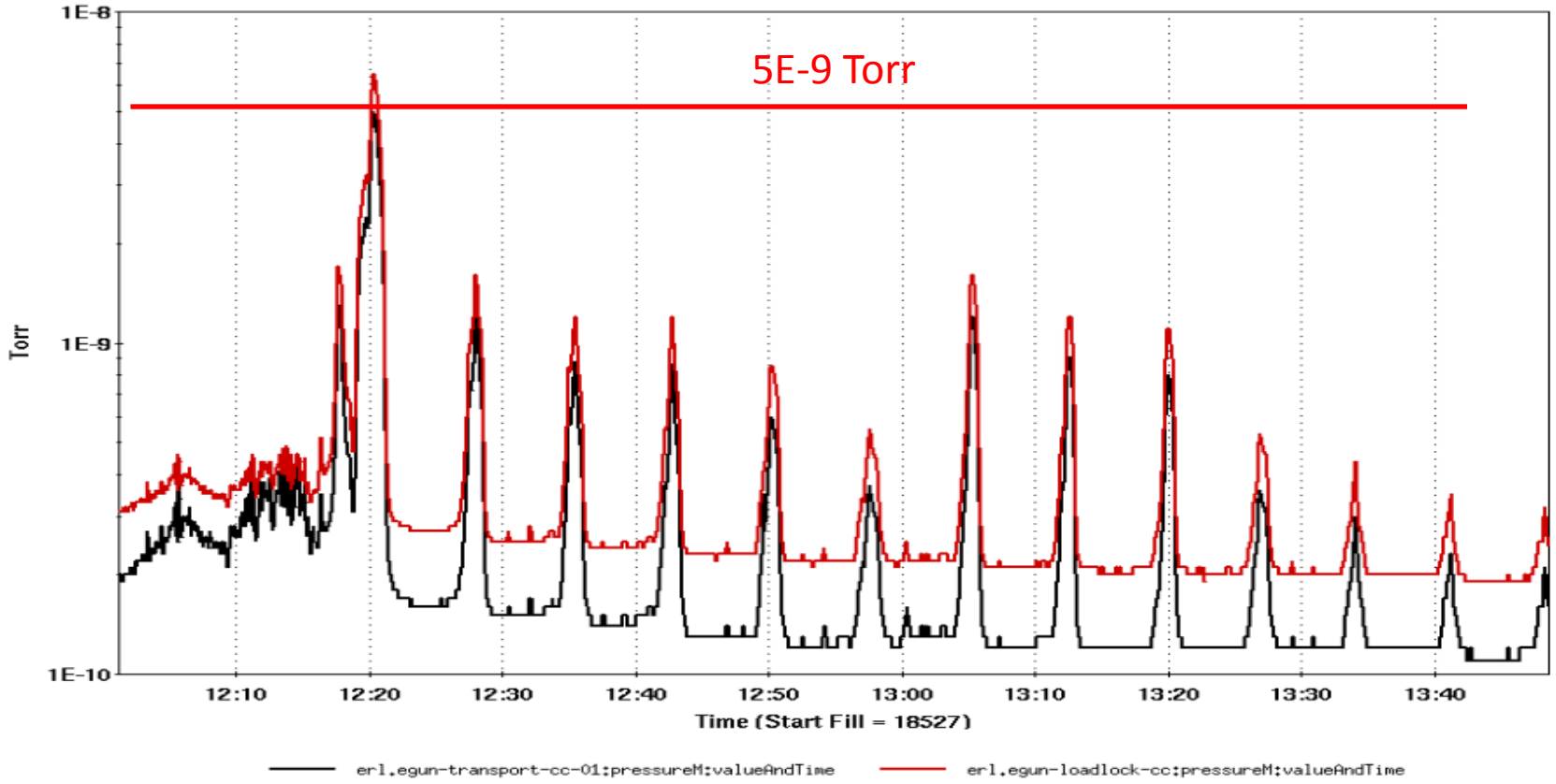
1. Nov. 2012 to Mar. 2013: Commissioned SRF gun cavity w/o cathode stalk inserted.
   →Demonstrated the SRF gun to be able to operate at 2.0 MV CW.
   →The amplitude stability is 2.3e-4 rms and the phase stability is 0.035 deg rms.
2. Aug. to Oct. 2013: Commissioned SRF gun cavity with copper cathode stalk inserted.
   →Found operational parameters: 1.85 MV, 180 ms, 1 Hz - limited by multipacting in the stalk.
   →Design a new multipacting-free cathode stalk with Ta tip for high QE => high current electron beam.
3. May 28 to Jun. 18, 2014: Commissioning with Cs_3Sb photocathode and dark current was observed.
   → Commissioned all subsystems and demonstrated system integration;
   → Understood the reasons for no photoemission beam and resolved the issues;
   → Demonstrated that the SRF cavity's performance was not degraded by photocathode insertion.
4. Nov. 17, 2014 to present: First photoemission beam commissioning
   → Observed photoemission beam, measured beam parameters and cathode's QE.

SRF gun beam commissioning configuration



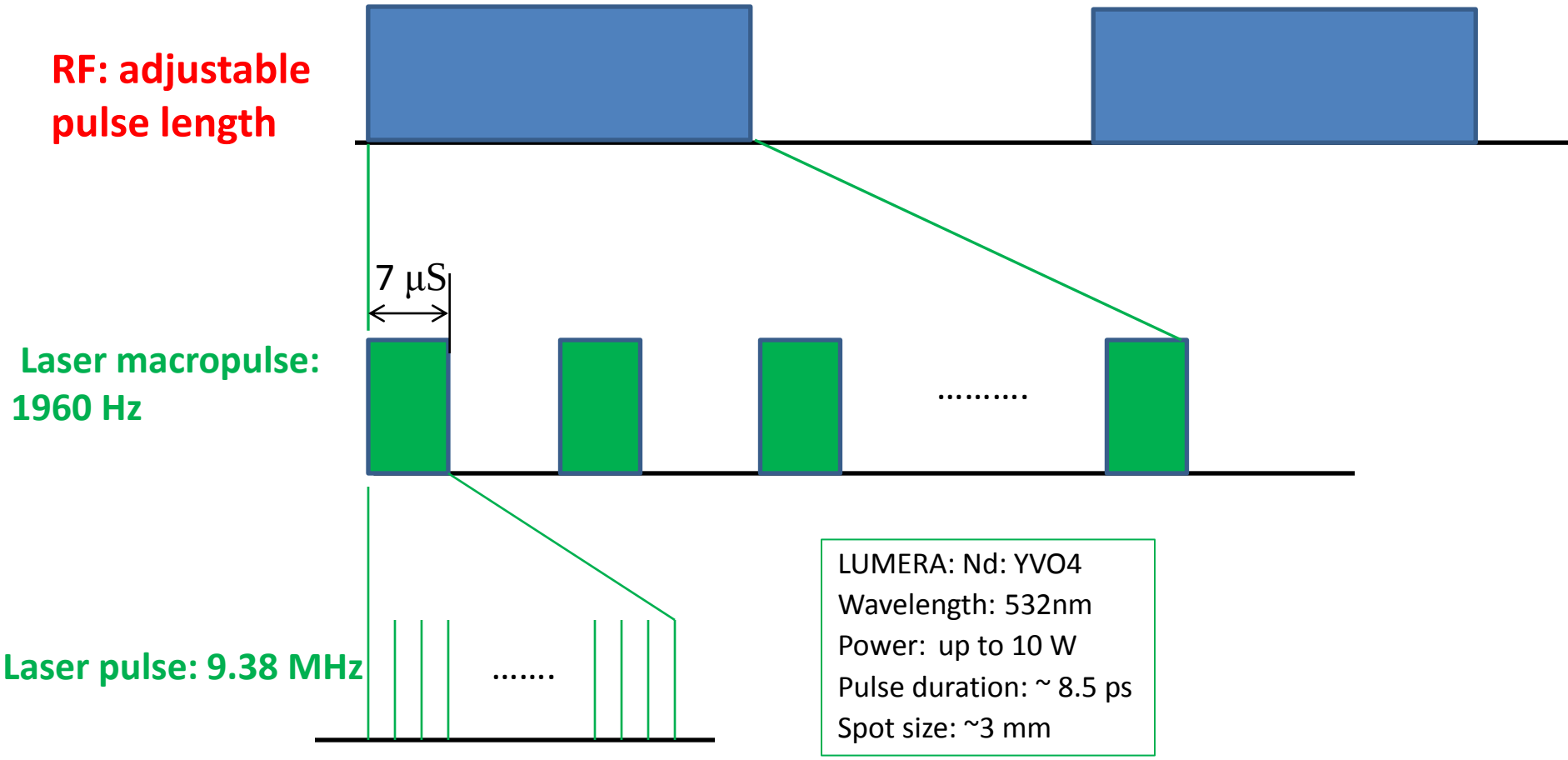
Prior to beam test: cathode stalk insertion

- Prior to inserting the photocathode, the QE was measured and estimated at 2.1E-4 in the transport cart, at room temperature.
- During the cathode insertion, vacuum was maintained below 5E-9 Torr.



- The QE was measured in the gun (77 degK) with beam: 1.2E-5.

Beam structure for lower beam power tests

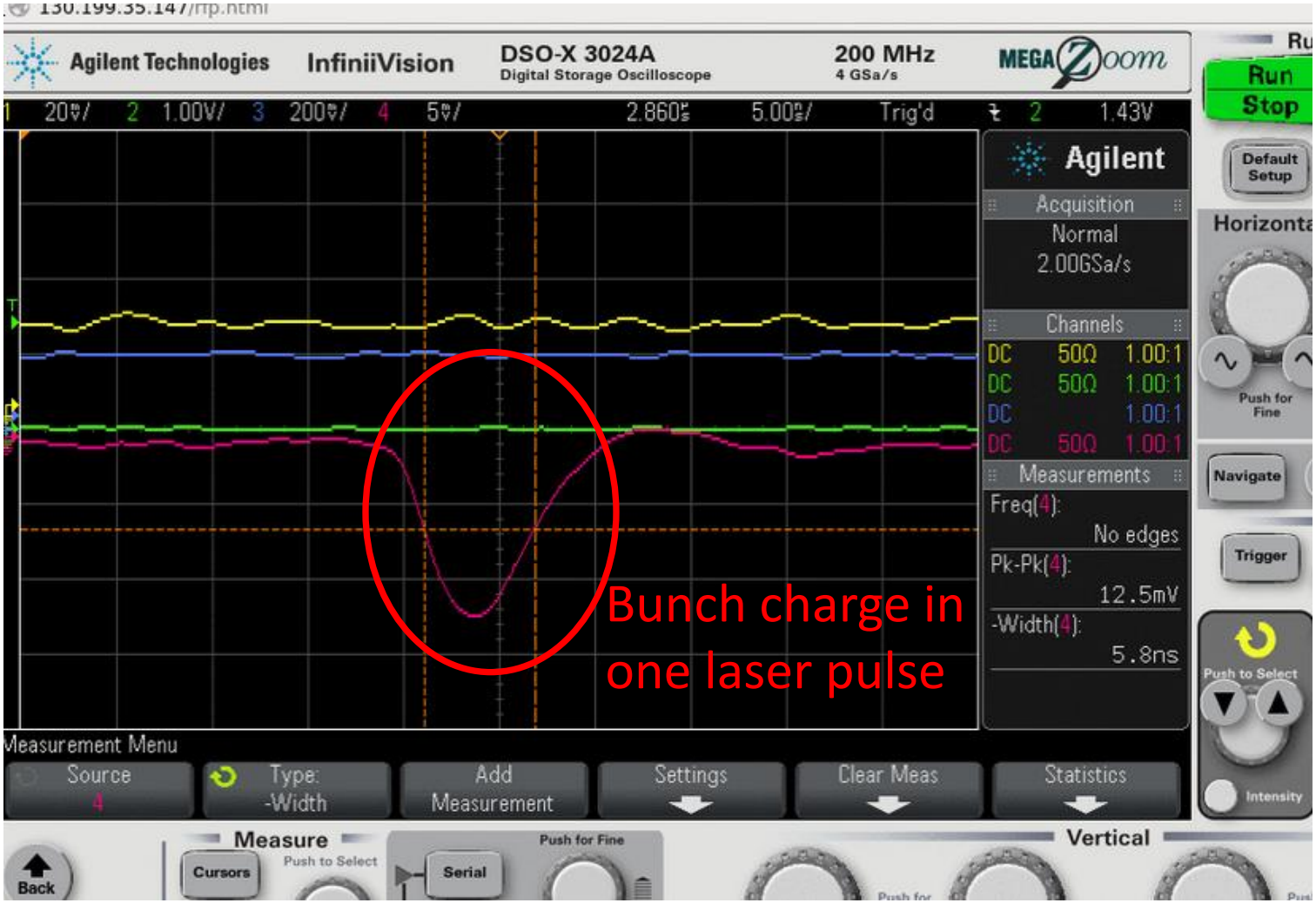


- The beam test has to satisfy DOE's approval "Commissioning Accelerator Safety Envelope (CASE) Credited Controls and Supports for ERL low power testing".
- The 7 μS pulse length is from ICT's response window

First observed beam by ICT

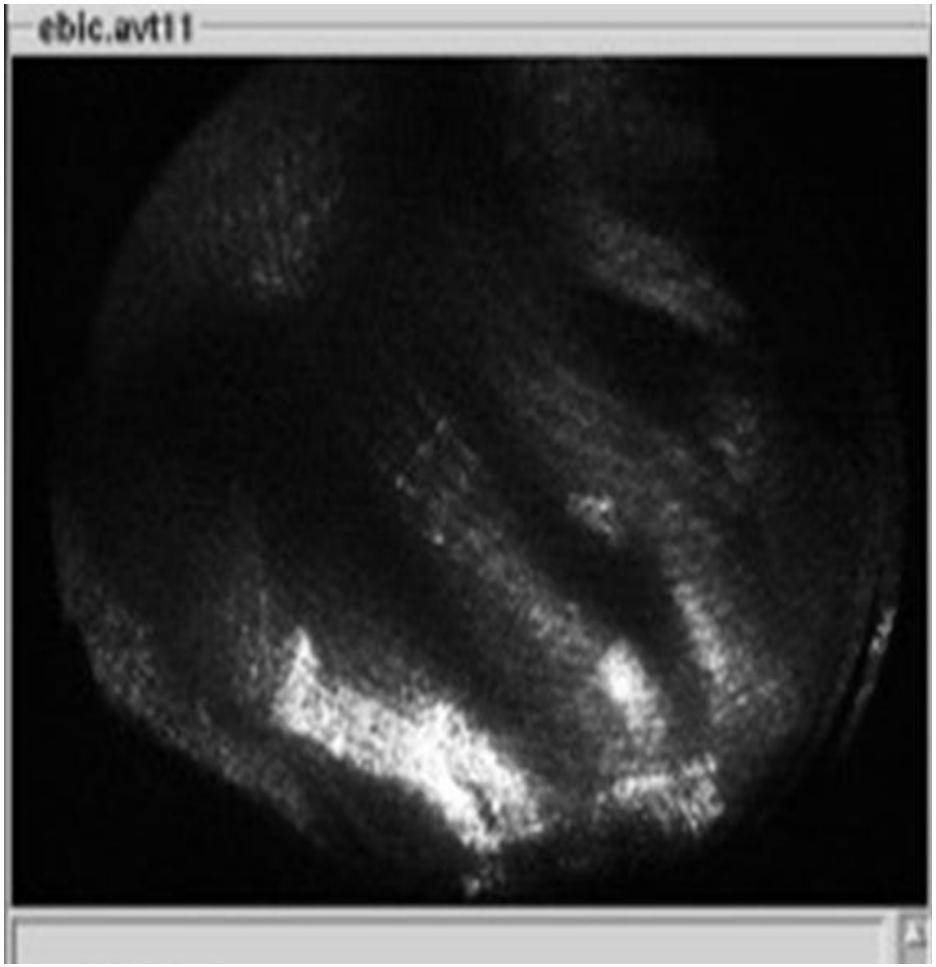
- Gun voltage is 1.2 MV;
- Laser power: 3 Watt average or 0.3 uJ per pulse

First observed beam: measure beam current by Faraday Cup

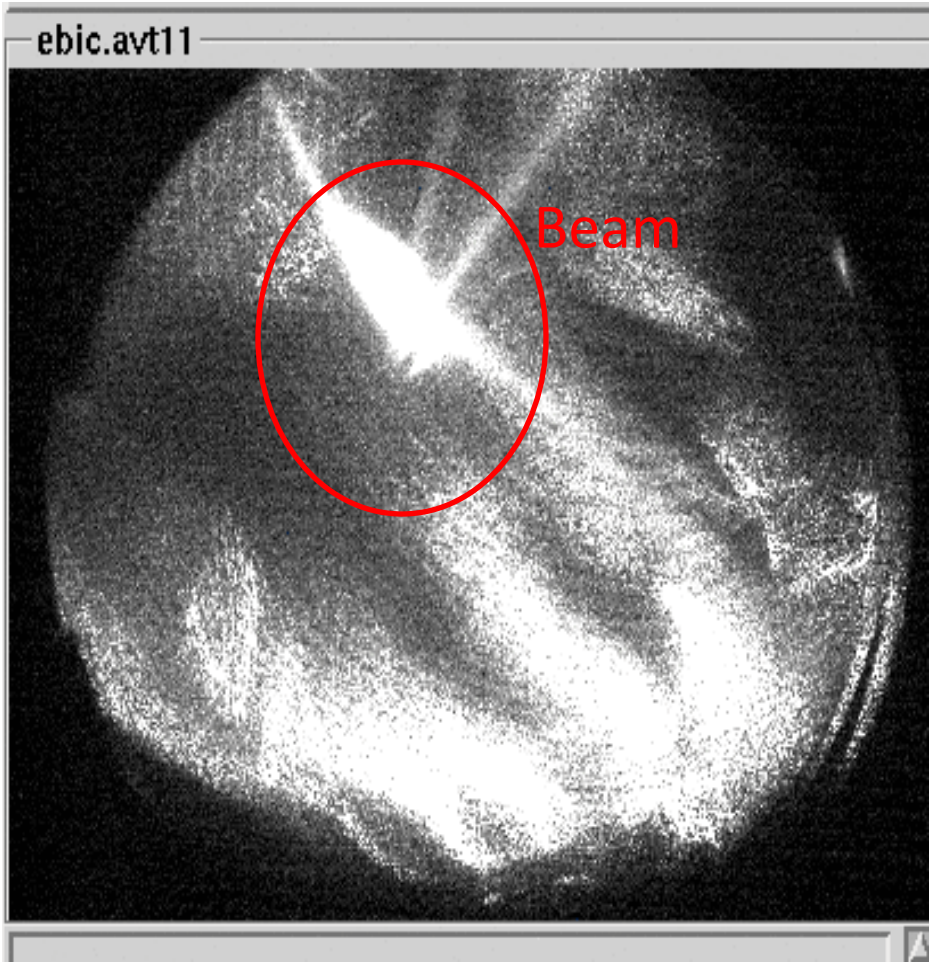


- Beam: bunch charge: 1.7 pC, current 2.4 nA.
- QE is 1.2E-5

First observed beam on Beam profile monitor

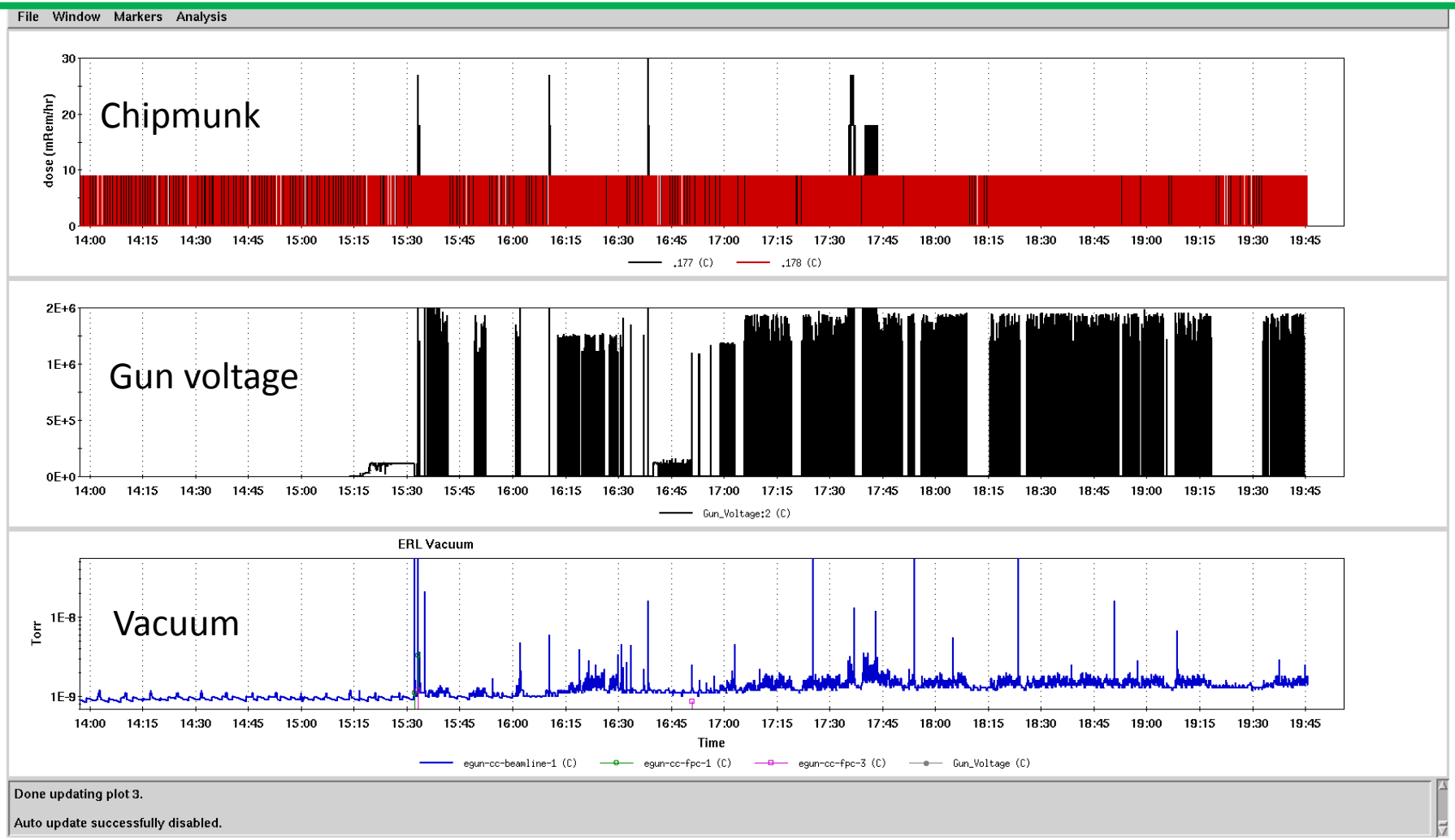


RF off



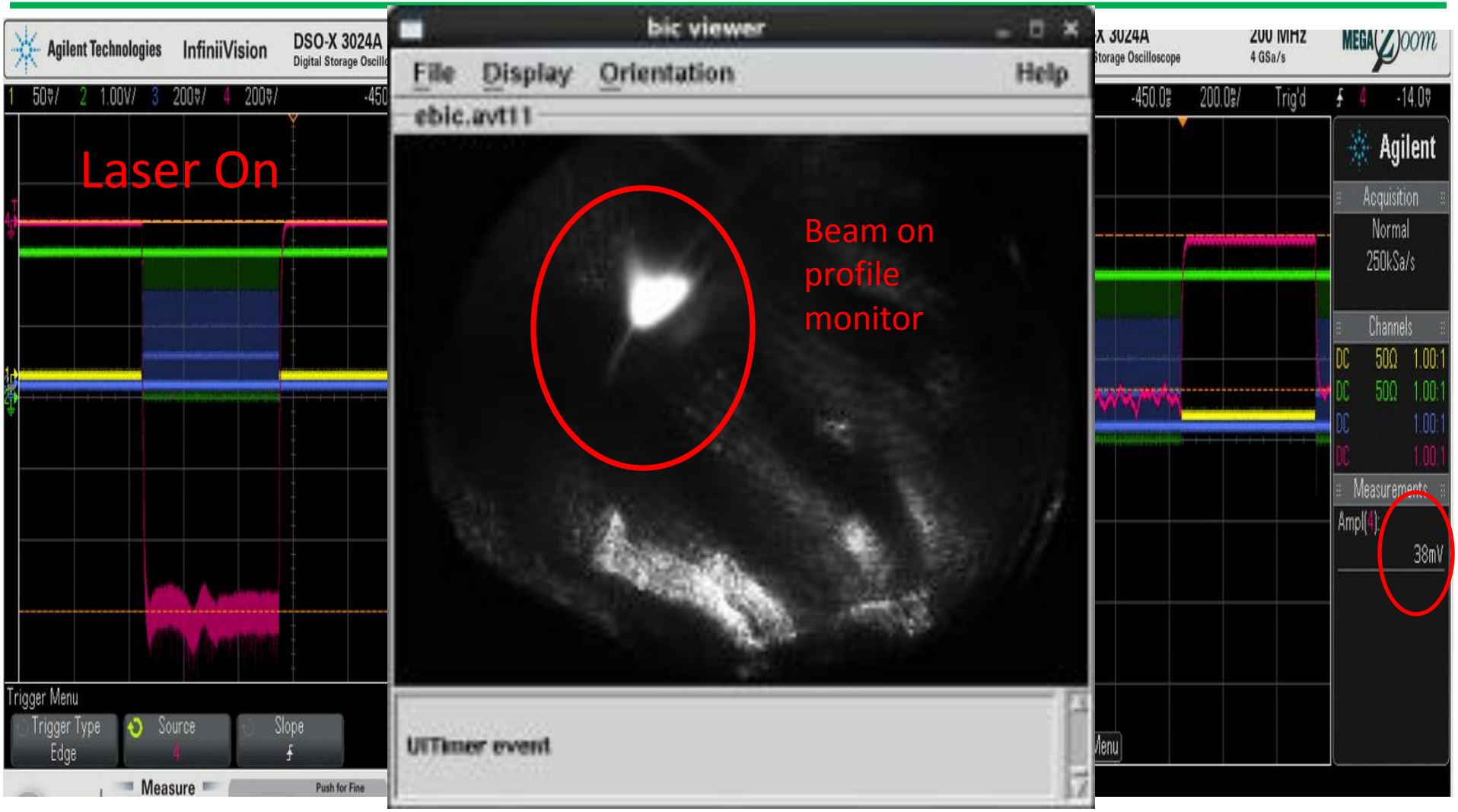
RF on

Excellent vacuum during beam test



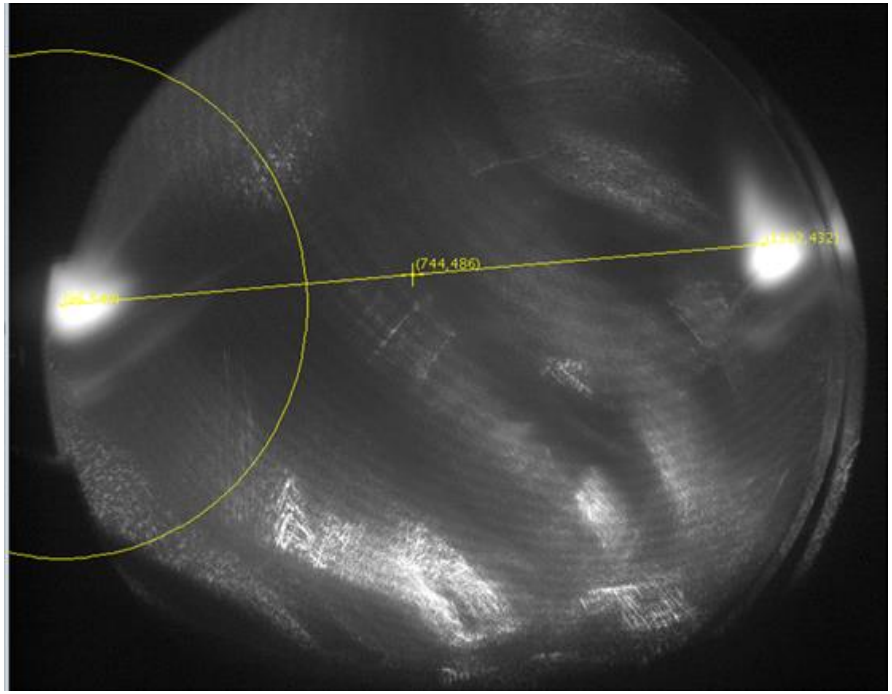
- The cathode stalk was conditioned very well before depositing photocathode.
- Vacuum setpoint was tight 5e-9 Torr after the valve was opened.
- There were only three vacuum trips before reaching 1.2 MV, 20 ms.

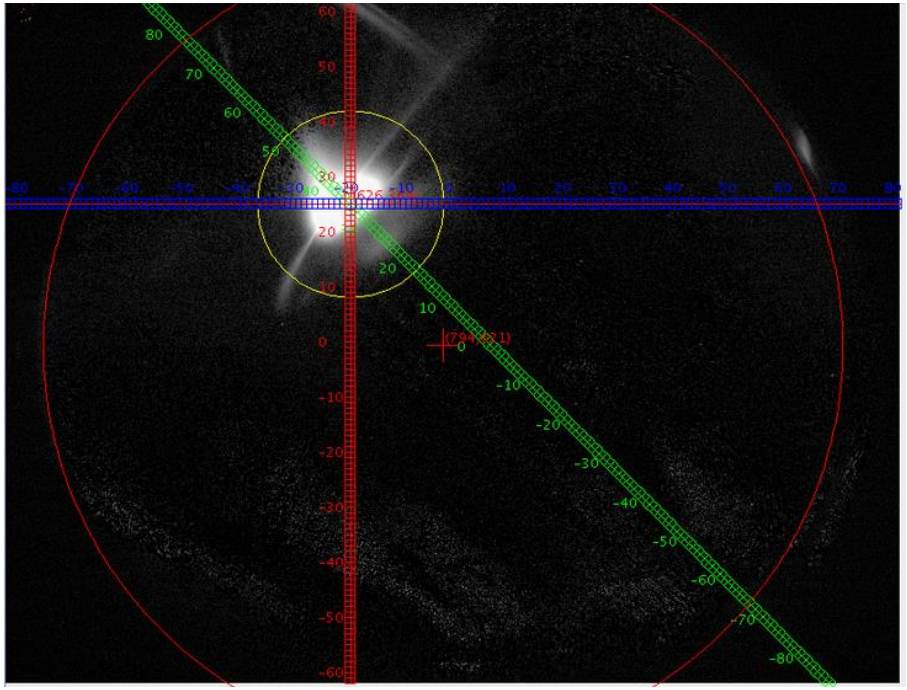
1 μA Beam

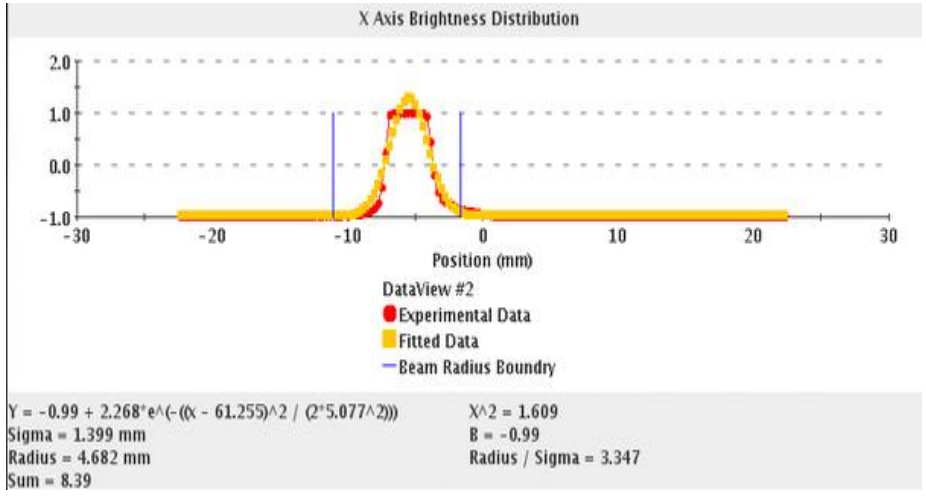


- Parameters: Laser: 6.08 Watt; RF: 1.2 MV, 500 ms;
- Beam: bunch charge: 7.7 pC, photoemission current 1 μA, dark current:38 nA;
- Focusing the beam with RT solenoid.

Beam parameters measurement

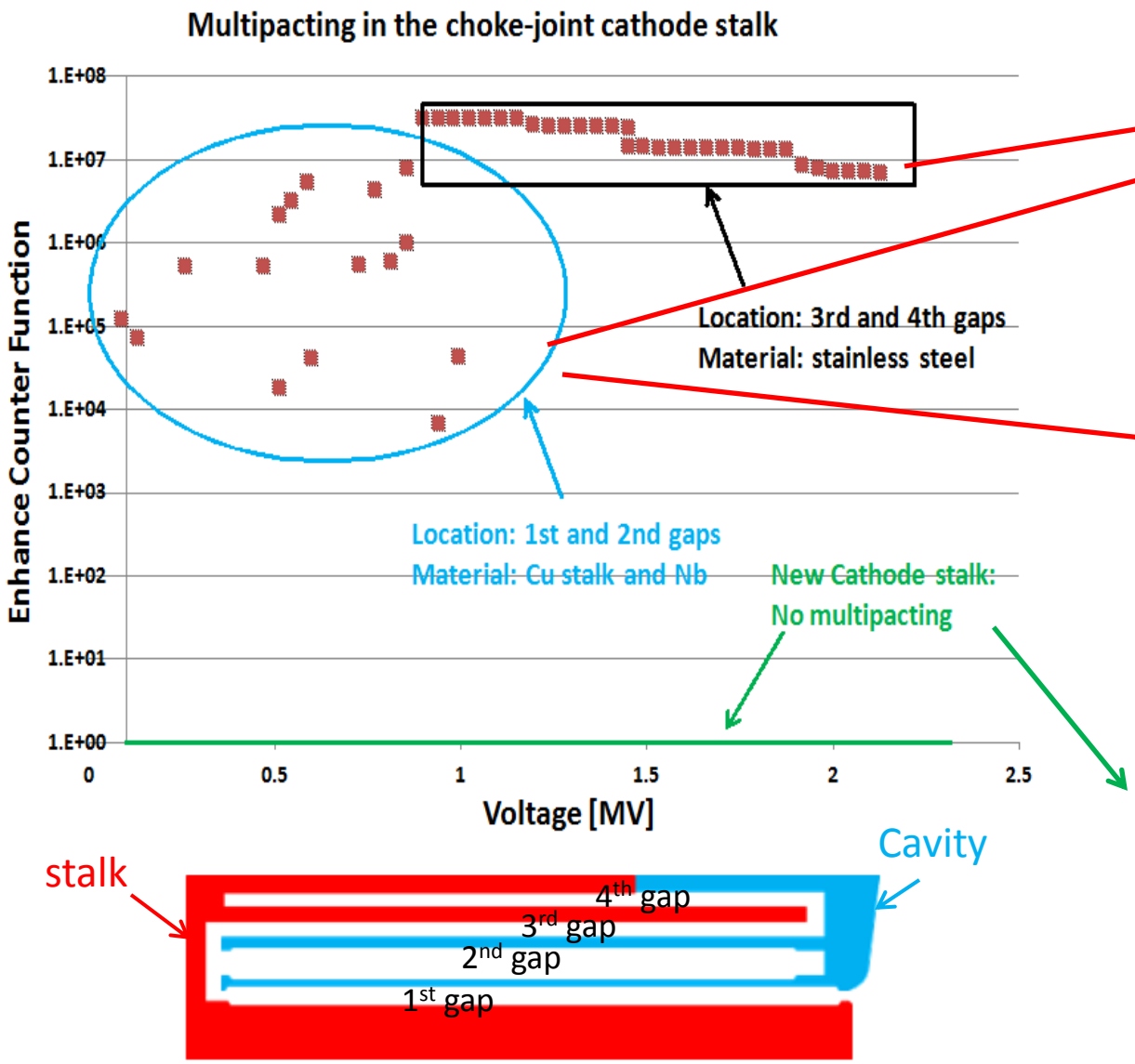


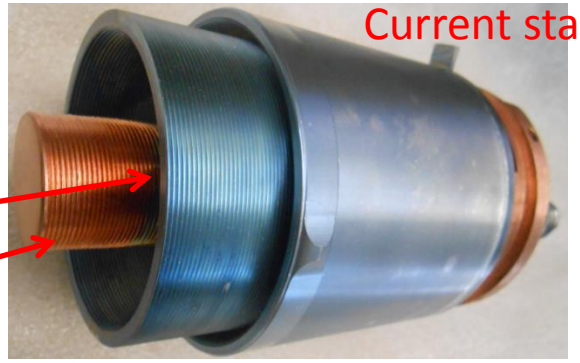


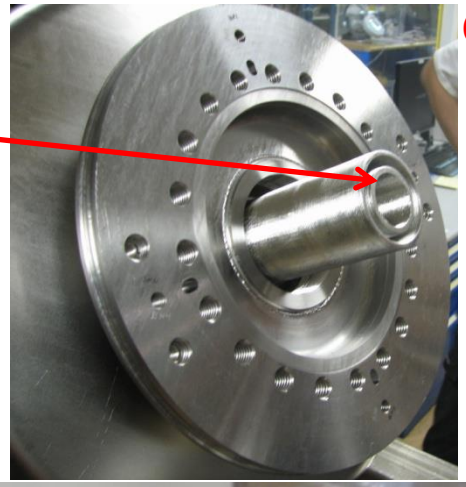


- Measured beam energy with steering and dipole magnet: 1.25 (+/- 10%) MeV;

New cathode stalk for high current operation





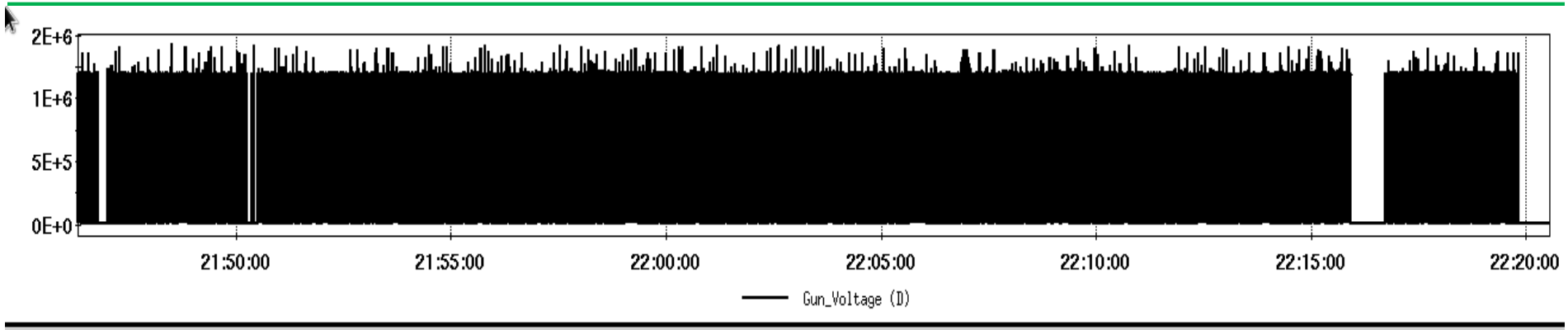


Summary

- SRF gun has made great progress in the past two years, with all the subsystems tested, installed and functioning well.
- The SRF gun cavity reached CW 2 MV without cathode stalk insertion.
- Mulitpacting occurred in the copper cathode stalk. A multipacting-free cathode stalk with Ta tip was designed, fabricated, and will be tested in Jan. This will assure the SRF gun can operate in CW mode up to 2 MV with high current performance.
- 1 μA photoemission beam (7.7 pC/bunch, 1.25 MeV) was measured during the first beam commissioning. This is a milestone for this gun.
- There is no sign of cavity degradation due to operating with photo-cathode.
- By mid 2016, the goal is to commission the full ERL with high current electron beam, i.e. a bunch charge >= 300 pC and an average current >=50 mA.

Backup slides

Cathode's QE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1E+6
5E+5
0E+0
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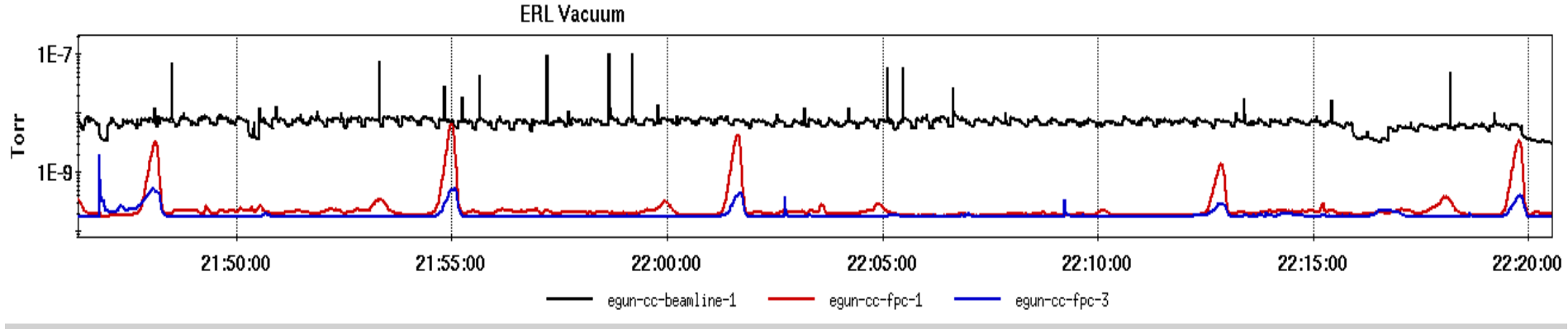
22:00:00
22:05:00
22:10:00
22:15:00
22:20:00
Gun_Voltage (D)


ERL Vacuum
Torr
1E-7
1E-9
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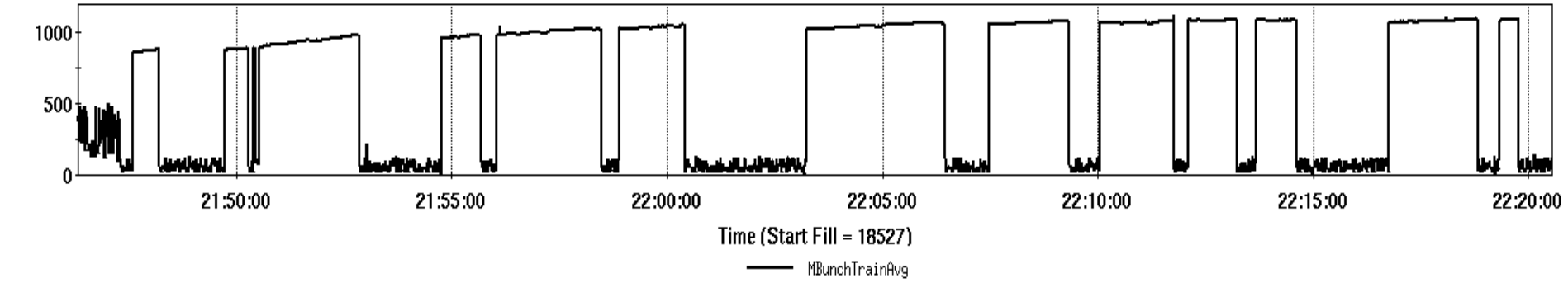
22:00:00
22:05:00
22:10:00
22:15:00
22:20:00
egun-cc-beamline-1
egun-cc-fpc-1
egun-cc-fpc-3


1000
500
0
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22:00:00
22:05:00
22:10:00
22:15:00
22:20:00
Time (Start Fill = 18527)
MBunchTrainAvg